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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 462

COMMENTS ON CRANKLESS ENGINE TYPES

From "Motorwagen," November 20, 1927

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 462.

COMMENTS ON CRANKLESS ENGINE TYPES.*

As long as there are cylinder engines with crank drive, individual constructors will strive to replace it by "simpler" constructional elements, either by converting the piston motion directly into a rotational motion, or by replacing the connecting rods and crank shaft with kinematic devices. The results of these efforts are engines which are constantly becoming more complex and sensitive and which, although they may prove satisfactory in the constructor's workshop, may lead to serious disappointments in endurance tests and in ordinary repair shops. The compactness of these engines is of some advantage for vehicles. On the other hand, however, it is a very much greater disadvantage, because the engine is thus rendered very difficult of access, while the expected saving in weight proves to be a delusion.

The greatest difficulty in these engines is the lubrication of the member which replaces the connecting rod and crank shaft.

The following pages describe the leading engines of this type, which have appeared during recent years.

*From "Motorwagen," November 20, 1927.

The Michell Crankless Motor Car Engine*

One of the main difficulties of the crankless engine is the lubrication of the wabble plate (called "slant plate" by Michell) and of the thrust block, since the oil is first thrown outward by centrifugal force and then forced between the thrust block and wabble plate by the constant pressure, and scraped away by the leading edge of the thrust block.

About twenty years ago, Michell constructed a thrust bearing for the propeller shafts of steamships. In these the steady and uniform direction of the propeller thrust had previously allowed only a small specific surface loading, requiring very great dimensions for the thrust collar.

Michell divided the stationary thrust collar into several movable thrust elements (Fig. 1), the center of support of which did not fall on the center of the bearing surface, so that when in motion they took an inclined position relative to the direction of motion, thus allowing the oil film to enter between the thrust collar and the tilting thrust block. While the thrust bearings with a rigid horseshoe collar permitted only a load of 4 to 5 kg/cm^2, the Michell bearing could support ten times this specific pressure.

Figure 2 shows the application of this principle to the thrust block of Michell's engine. Between the piston and wabble plate there is a hemispherical thrust block, which adapts itself

*Figures 3-6 were taken from "Engineering," October 5, 1923, pp. 429-432.

to the different degrees of inclination of the wabble plate, and which is set off the center of the sliding surface. The point of support of the thrust block, as viewed in the direction of motion, lies behind the center of pressure of the oil layer, about which point the thrust block tilts. Due to the somewhat raised and rounded leading edge of the sliding surface, the oil film easily gets between the latter and the wabble plate and forms a wedge-shaped section.

The hemispherical thrust block and the sliding surface consist of one piece of steel with a white-metal lining (Fig. 3).

In spite of this clever construction of the thrust block, abundant lubrication of the wabble plate is still necessary.

A gear pump at the bottom of the engine housing pumps the oil into a tank, from which it flows by gravity to the pressure pump, which in turn delivers it at 0.35 atm. to several nozzles from which it is sprayed against the wabble plate and cam shaft drive (Fig. 4). The aluminum pistons are thus lubricated by an oil spray in the wabble-plate housing.

The 8-cylinder vehicle engine shown in Figures 3-5 has battery ignition, the distributor being set on the vertical shaft, which also operates the water pump (Fig. 5).

The weight of the engine is 230 kg which, with an abundant use of light metals could have been considerably reduced. The accessibility of the individual elements for the purpose of inspection, is (according to the builder) better than that of a

normal engine, but it is possible for one to have a different opinion.

The characteristics of the engine are compared in Figure 6 with those of a 16% larger P.K.W. engine, although the Michell engine reaches a speed of 3000 R.P.M. with an output of 60 HP. The higher mechanical efficiency of the Michell engine as compared with the normal crank shaft engine is worthy of notice.

The English manufacturer is also working on the design of a two-cycle Diesel engine on the same principle. An 8-cylinder engine, of 120 mm bore and 136 mm stroke, developed 50 HP. at the normal speed of n = 750 R.P.M. and 75 HP. at n = 1000 R.P.M., which is not especially remarkable.

It is rumored that the English Air Ministry is working on a crankless type of engine for aircraft, through the hollow shaft of which a small "revolver cannon" fires, this engine apparently being of the Michell type.

Piston compressors are built also on the same principle.

In England and America endeavors are also being made to apply the fundamental principle of the Michell engine to heavily loaded thrust bearings.

The German Michel Engine of the Michel Engine Co., Ltd., Kiel

This is a Diesel engine working on the two-stroke cycle, although the cylinder power is not generated by a single piston, the necessary total piston area being subdivided between three correspondingly smaller pistons with only one common combustion chamber. The three pistons are arranged radially 120° apart and work on a crosshead with the bearings a mounted on each side of it (Figs. 7 and 8). The rollers work on the "positive" cam shapes a' when the engine is running. When not running and when starting, any retrogression of the pistons is prevented by the "negative" cam shape b', on which the corresponding rollers b do not rest, however, when the engine is in operation. The housing and the cam shapes stand still, while the pistons and star-shaped cylinders, with the injection valve and fuel pump, revolve. The introduction of fuel, lubricating oil, and cooling water into the revolving cylinders is said to cause no difficulty.

The use of three small pistons has several advantages:

1. Very good scavenging, since one piston controls the exhaust gases, while two pistons control the scavenging air.

2. The piston diameter of 180 mm for powers of 120 to 1000 HP. (obtained by arranging several radial groups

of cylinders behind one another), facilitates the temperature control.

3. The effect of the reciprocating masses is eliminated and the functioning is smooth and uniform.

The cam shape is so constructed that the pistons execute four or six working cycles per revolution of the star-shaped cylinder, thus automatically reducing the engine speed, (for example), from 660 to 110 R.P.M., which is of considerable importance in marine installations.

In spite of this, a proposed Michel engine of 1000 HP. with a propeller shaft speed of 120 R.P.M., weighs about 42,000 kg, as against 128,000 kg for a four-stroke-cycle Diesel engine of 1000 I.HP. at 135 R.P.M.; that is, the Michel engine with 50 to 60 kg/HP, is nearly twice as heavy as a submarine Diesel engine which weighs 25 to 30 kg/HP at 350 to 450 revolutions per minute.

Whether the poor accessibility of the inclosed Michel engine with its revolving fuel pumps and nozzles will give any trouble in an endurance test, and whether (especially in the case of the large units of the Michel engine) it is off-set by the saving in volume and weight, is still to be proved. In the recently built engines the roller bearings in the crossheads are said to be replaced by plain bearings, evidently due to difficulties with the rollers.

Figures 9 and 10 show the 300 HP. six-stroke airplane engine of the Frenchman E. Laage, of the 1923 type, with 16 air-cooled cylinders in two opposite rows revolving with the propeller shaft and with their axes parallel.

The opposite pistons are fastened together in pairs and work by means of a roller on the stationary cam shape.

The engine has also disappeared.

The "Ali" outboard two-stroke engine, with four stationary cylinders parallel with the axis of the shaft and four scavenging pumps located opposite the working cylinders, is shown in Figures 11-13 (V.D.I. - "Zeitschrift des Vereines deutscher Ingenieure," 1925, p.1405). Between the working cylinders and the pump cylinders lies the wabble plate which here, however, has no rotational motion, but only a peculiar oscillating motion, by which each point of the circumference passes through its lowest and highest points once during each revolution of the engine shaft. This motion of the wabble plate is transmitted by two thrust ball bearings to the engine shaft.

Although this engine skilfully eliminates the difficultly lubricated revolving thrust bearings and thus permits the expectation that it will work well, it has not yet come into commercial use.

The American Experimental Institute for Aviation built a four-stroke-cycle aviation engine of the same or a very similar

type with ten pairs of opposite cylinders, but abandoned it on account of difficulties with the thrust bearings

Figure 14 shows the American Fairchild Caminez 150 HP. airplane engine of 1928. In this constructional type (by no means new), the pistons act directly on a lemniscate-shaped cam which makes only one revolution for every two working cycles of the piston. The propeller speed is therefore automatically reduced to half the hypothetical engine-shaft speed. The lemniscate-shaped cam permits, furthermore, perfect balancing of the masses and equal working strokes in the opposite cylinders.

The light-metal pistons are connected by steel links, so that they cannot get away from the cam. The piston pin lies in a bronze bushing.

The constructor of this cam-type engine did not have a free hand in the choice of the cylinder stroke and bore, these being established, for a desired stroke volume, by the most favorable stroke-bore ratio, whereby the bore is always greater than the stroke.

The data for the Fairchild Caminez engine are:

Stroke, 115 mm

Bore, 143 "

Compression ratio $\epsilon = 5.2$

N = 150 HP. at n = 2400 R.P.M. (propeller speed 1200 R.P.M.)

Flying weight without starter but with propeller hub 164 kg, or about 1.1 kg/HP.

Steel cylinders with aluminum heads screwed on hot.

Only one rocker for each exhaust and intake valve on the propeller shaft, which revolves at half the speed of the engine shaft.

Lubrication by pressure pump, a scavenge pump forcing the oil through a filter back into the oil tank.

In spite of the very high performance of 20.5 HP./liter for air-cooled engines, its weight of 1.1 kg/HP is not particularly low.

An obvious disadvantage of this engine is that it requires very accurate mounting, since too great a clearance between pistons and cam, by reason of the absence of a damping oil layer, results not only in a great noise but also in a rapid wearing of the rollers. The advantage of low propeller speed is not great enough to warrant such an expensive and sensitive type of construction. The normal clearance between cam and rollers is 0.4 mm, though the engine is said to be able to function with 0.9 clearance.

In this connection, we should mention still another English engine (Fig. 15), in which the pistons work through claw and rocker arms on the peculiar engine shaft, whose three portions revolve in two inclined binding pieces. The constructor is in

opposition to the fundamental rule that the engine shaft should constitute the backbone of an engine and should accordingly, be as rigid as possible.

He sees an advantage in the fact that the engine shaft is not under the cylinders, but to one side, where it can be easily inspected. Thus the height of the engine is reduced, which, in the inventor's opinion, predestines this engine for aircraft, while the smaller connecting rod oscillations should obviate the need of crossheads in large Diesel engines.

An interesting and complicated example of a crankless engine, from both the kinematic and constructive points of view, was built a few years ago in America, namely, the Nedoma-Najder airplane engine (Fig. 16), in which the cylinders and the wabble plate both revolve.

The stationary hollow shaft W rests at both ends of the engine on the bearings A. Around it revolve the five cylinders Z, and the housing G, which carries the flange N, for the propeller hub. The housing revolves on the hollow shaft W, in long bushings and in a ball bearing A, at the propeller. A bushing provided with a toothed gear Z_1, is screwed to the front end of the revolving housing. Z_1 meshes with the front planetary gear Z_2, which transfers its motion to the geared bushing Z_3, which revolves at the same speed as the housing G, but in the opposite direction. The bushing B, is keyed to

Z_3, on which the wabble plate revolves on two ball bearings, being carried along by the arm C, which is attached to the housing.

Due to the opposite motions of the bushing B, and the wabble plate T, the latter passes during each revolution, through its maximum and minimum distance from each of the five cylinders, executing thereby a complete working cycle in each cylinder for each revolution of the housing. The five aluminum cylinders of 70 mm diameter and 86 mm stroke, are each controlled by a single slide valve. The slide valves are made of cast iron and the pistons are made of aluminum.

The slide valves are actuated by five shafts provided with helical grooves, which in turn have five gears which mesh in a gear rim attached to the stationary hollow shaft. Two of these gears also operate the two oil pumps.

With this monstrous construction the inventor thought to produce a light aircraft engine which, at n = 1400 R.P.M. and N = 40 HP., would weigh about 74 kg, corresponding to 1.83 kg/HP.

Translation by
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for Aeronautics.

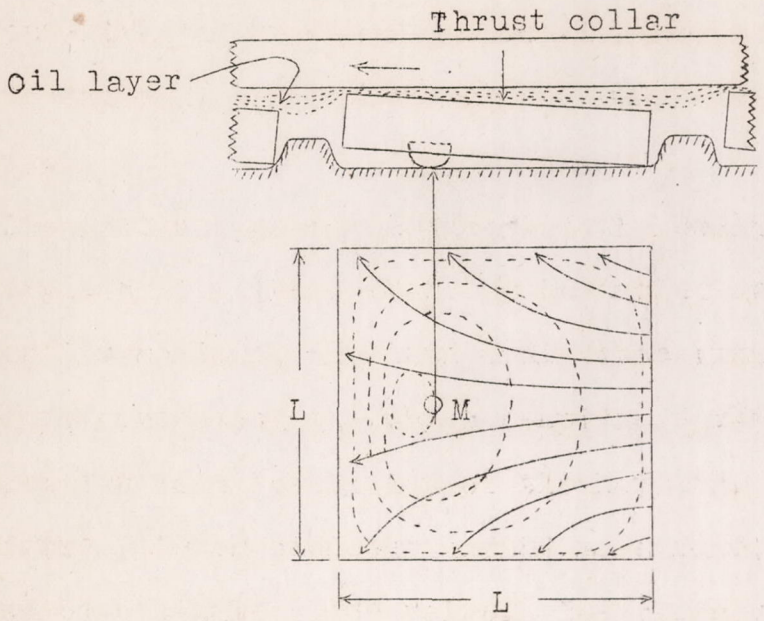


Fig.1 Michell thrust bearing for shafts of ship engines.

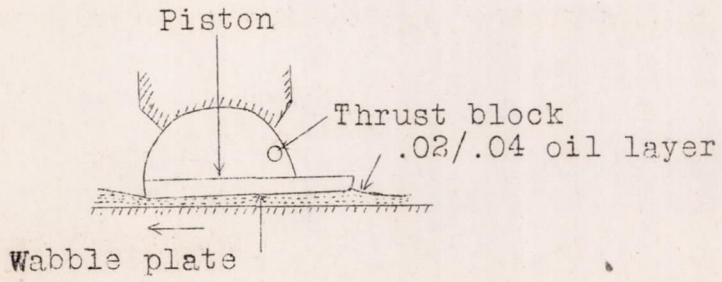


Fig.2 Michell thrust bearing in crankless engine.

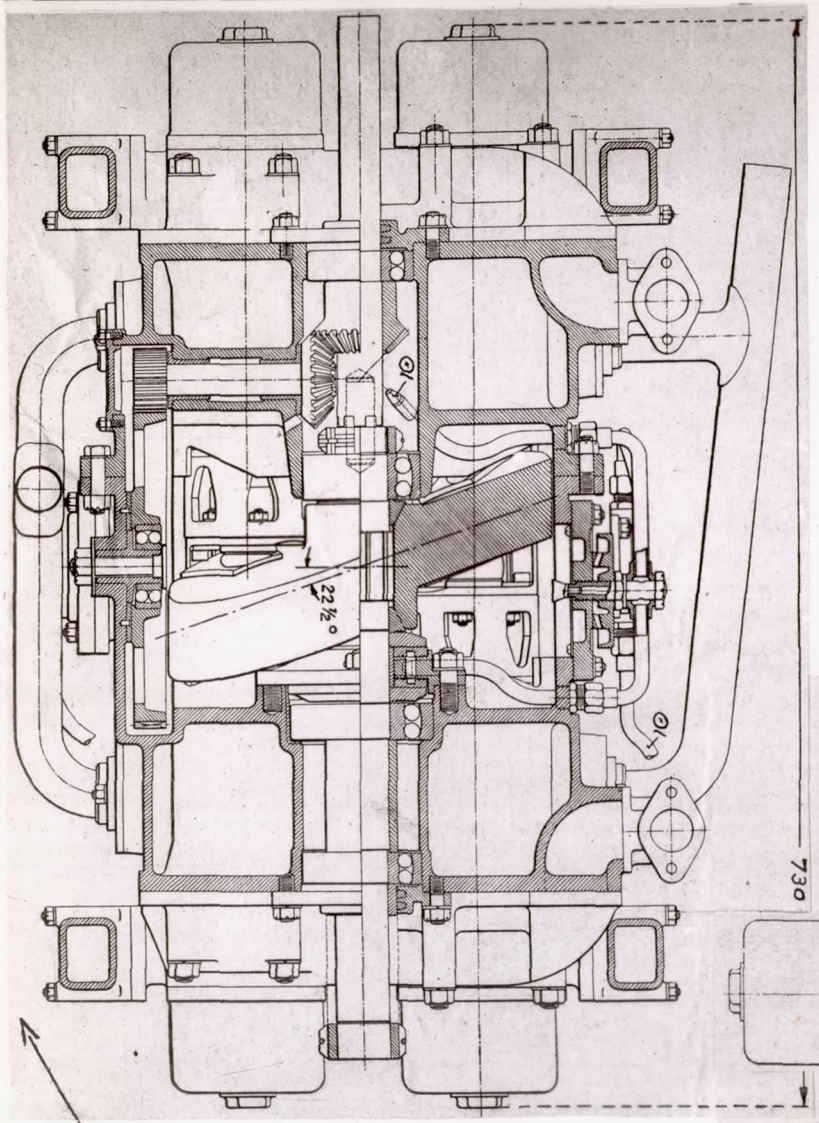


Fig.4 Longitudinal section

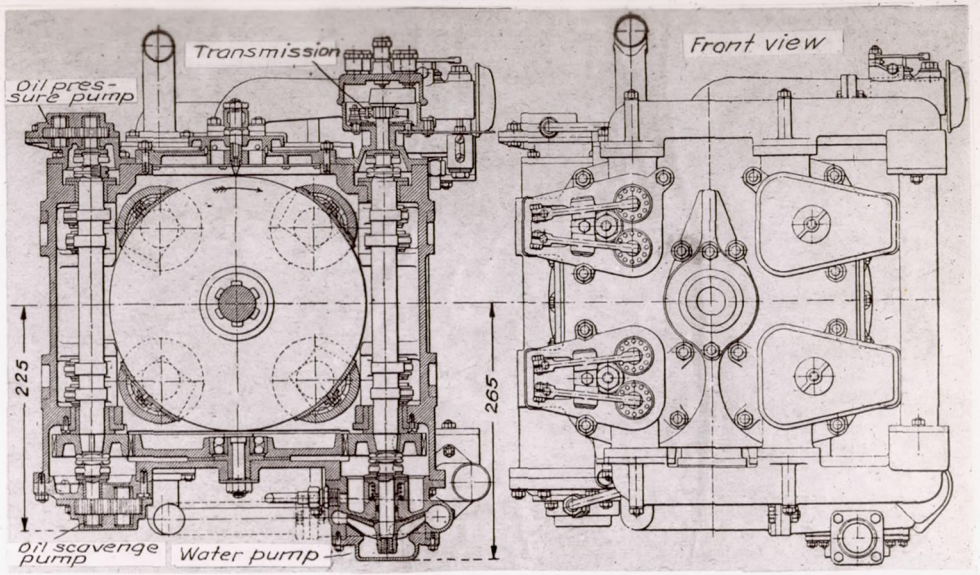


Fig.5 Section through engine in front of wabble plate

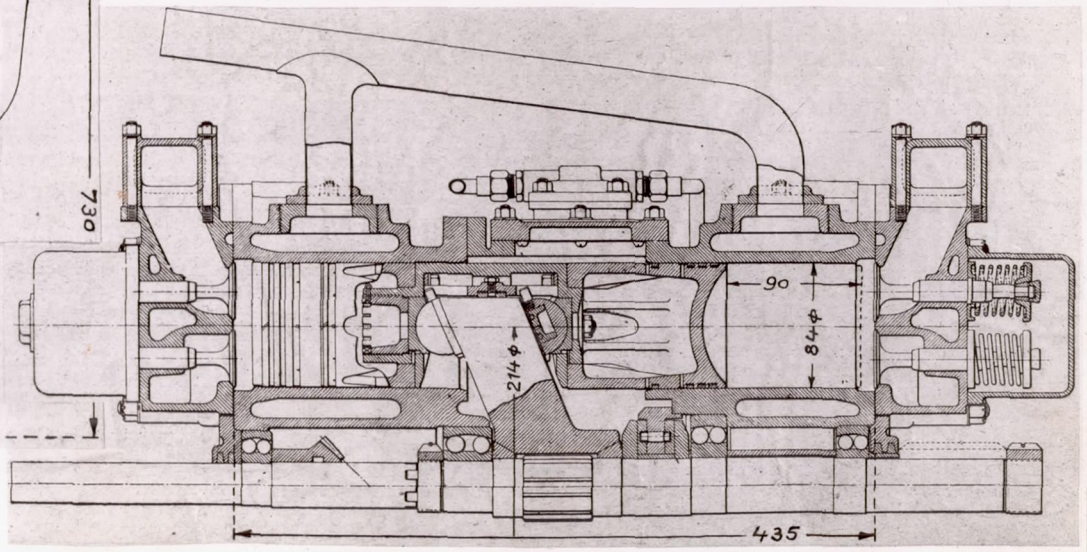
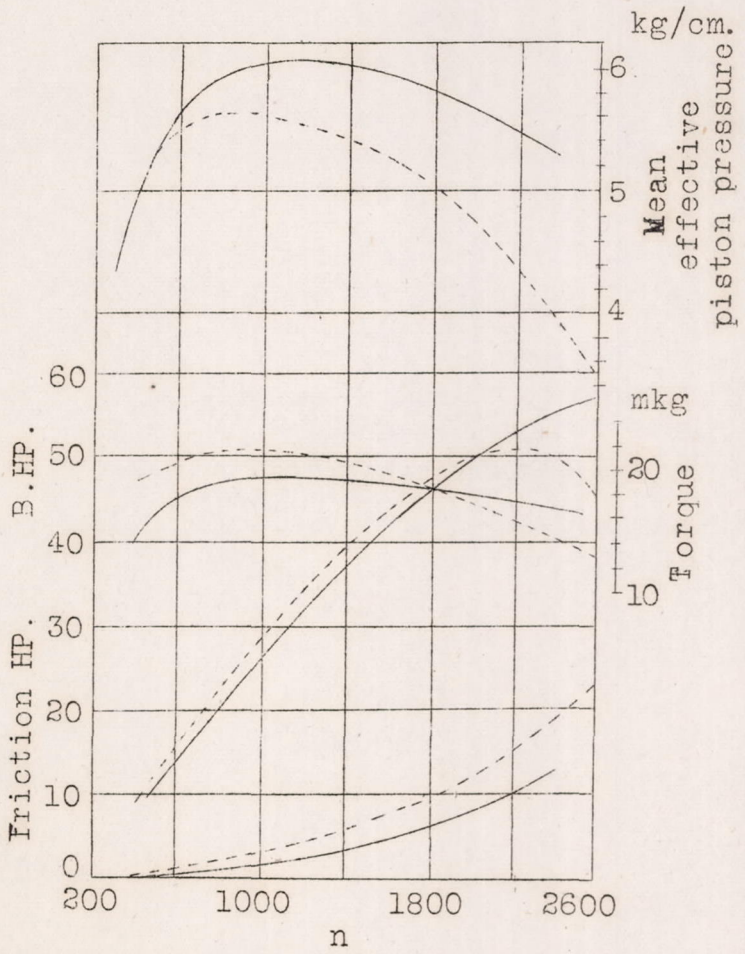


Fig.3 Section through piston and valves.

Figs.3,4,5



Michell Motor 8(84 ϕ× 90)=4, 1 ————————

American motor car 6(88 ϕ×127)=4.65, 1 - - - - - - - -

Fig.6 Comparison between Michell engine and American motor car engine.

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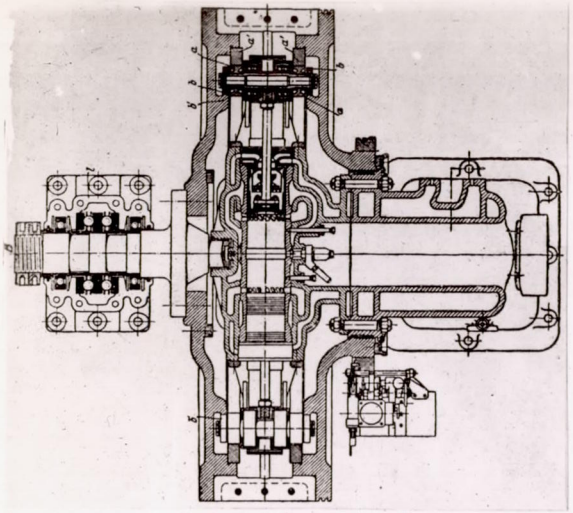
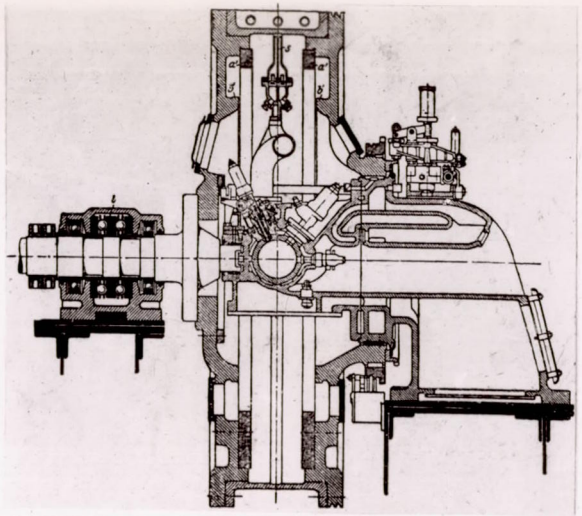
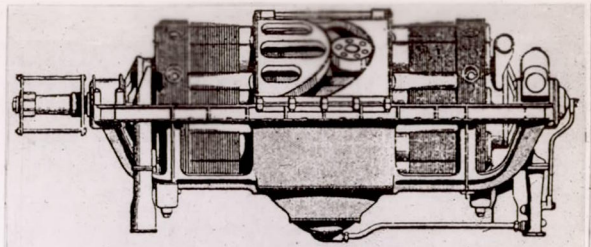
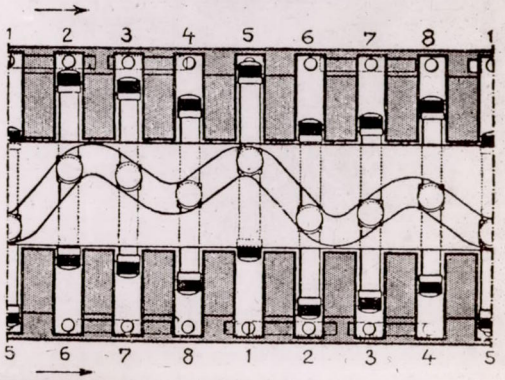


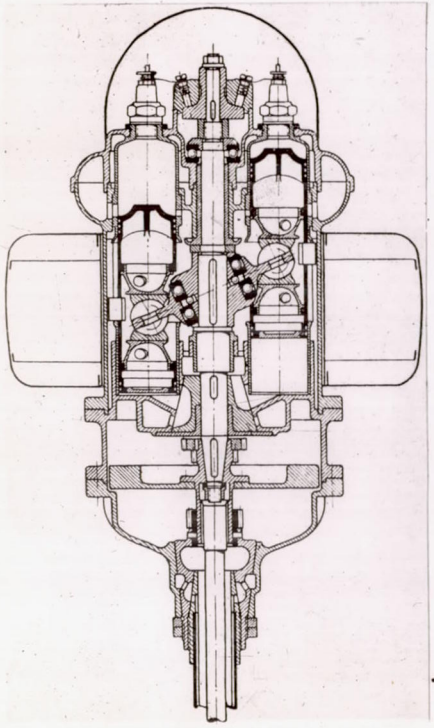


Figs. 7 & 8 Section through Michell Diesel engine.





Figs.9 & 10 16-cylinder six-stroke rotary engine of E.Laage. 1,intake mixture;2,compression 3,expansion; 4-5,exhaust; 6, intake of scavenge air; 7-8, partial exhaust of scavenge air



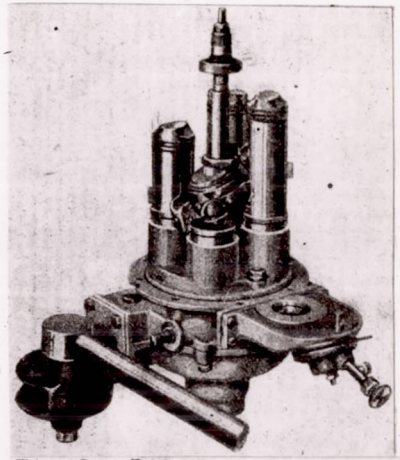


Fig.13 "Ali" outboard engine with cylinders removed, with a scavenging piston without working piston. Carburetor below at the right.

Fig.12 Sections between two cylinder pairs above the wabble plate.

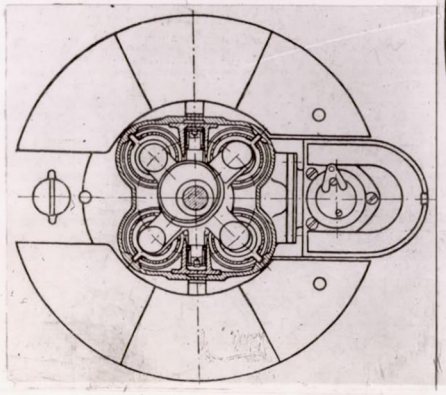
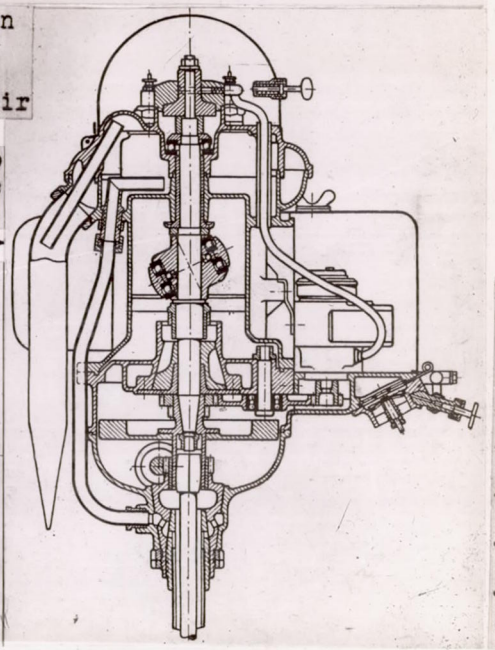


Fig.11 Section through cylinder of outboard engine "Ali".



Figs.7,8,9,10,11,12,13

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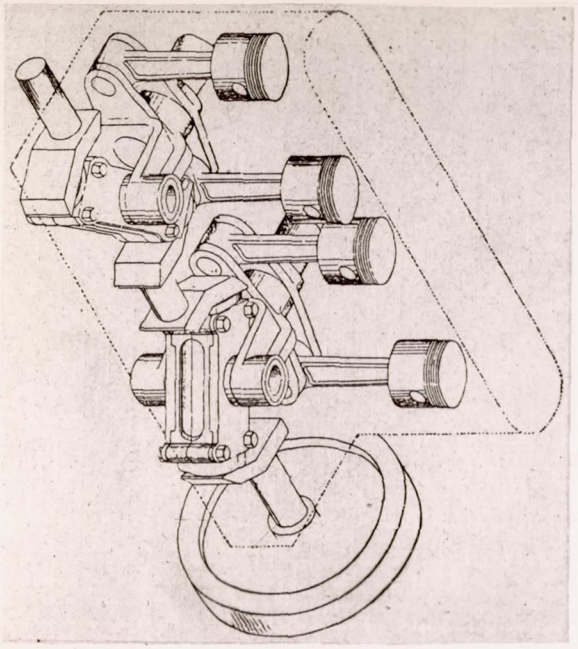
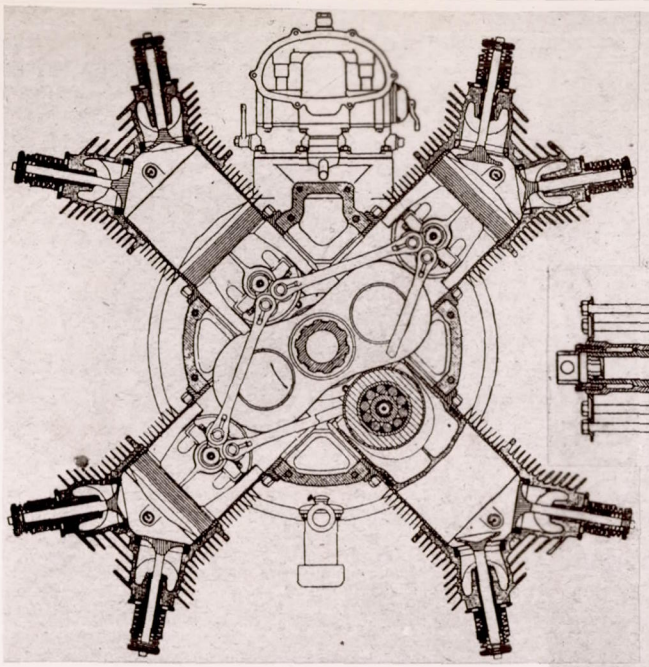


Fig. 15



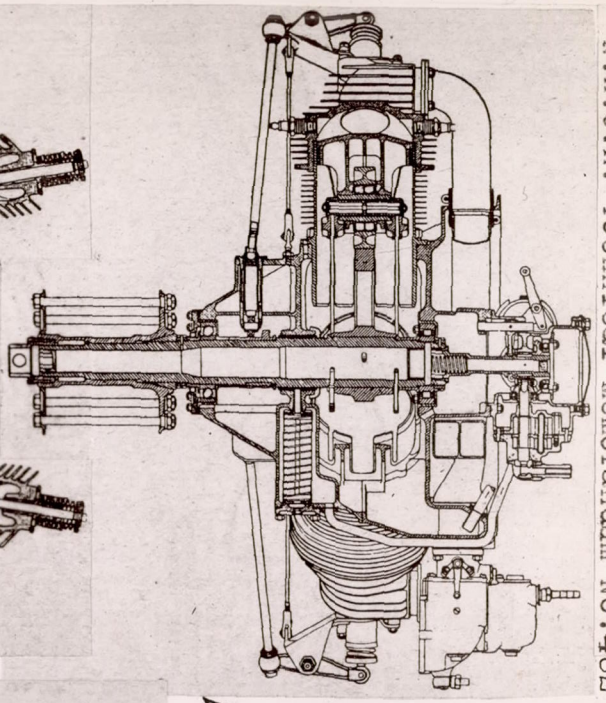


Fig. 14

Fairchild-Caminez aircraft engine

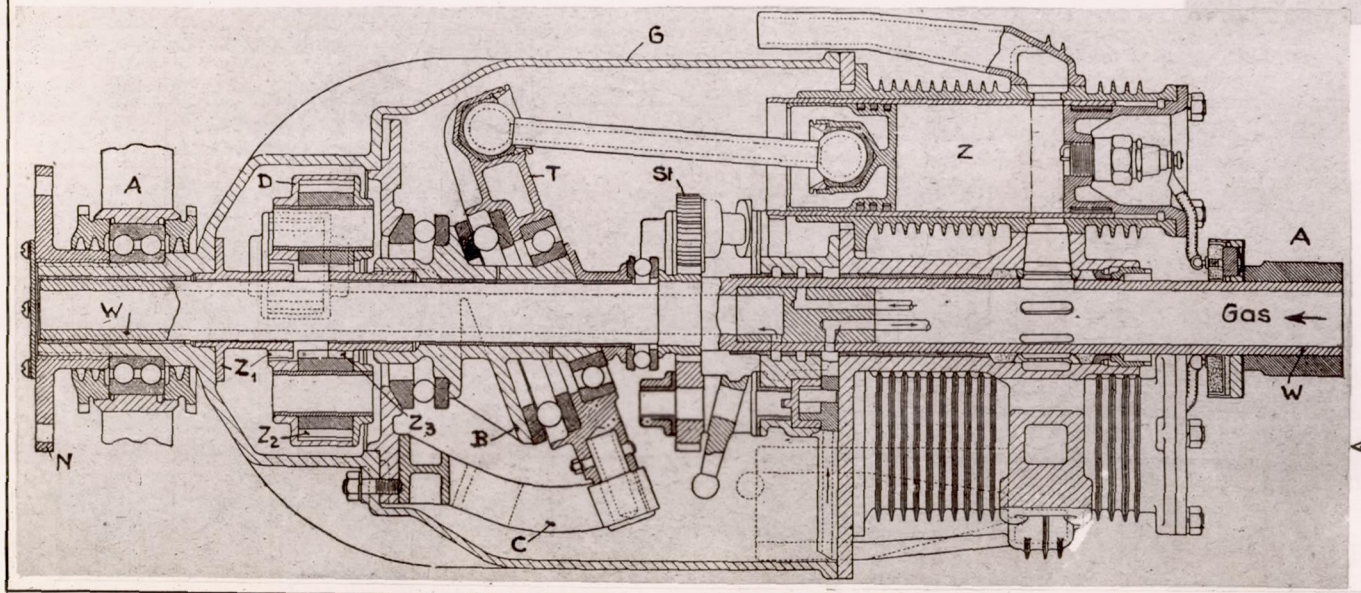


Fig. 16

Nedoma-Najder aviation engine.

Figs. 14,15,16